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Reducing Military Aircraft Engine Development Cost through Modeling and Simulation

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Introduction

By the year 2010, more than half of the Air Force fighter fleet will consist of existing F-15's, F-16's and F-117A's -- well beyond their original expected service life. Nonetheless, the need exists to replace our most aged fleets of aircraft despite the uncertainty of future defense budgets. Cost may be the determing factor that shapes the look of our military's future force structure. The goal of today's military acquisition reform process is to meet user system and service operational requirements while focusing on minimizing costs associated with life cycle cost. The term cost as an independent variable (CAIV) has been given to this process in which consideration is given, up front and early, to minimizing acquisition and deployment costs, maintenance strategy, reliability, maintainability and availability. Acquisition costs include both the development process and system production.

One factor that inhibits the introduction of new weapons systems into our future force structure is the exorbitant cost of developing new systems. Although the development cost for a new system is but a small fraction of the total systems life cycle cost, it is arguably the most significant element. Development cost is the first cost incurred for a new system and, in an era of tightening budgets, it tends to dominate all other system factors, including the performance and capability improvements offered by a new system. Also, there are fewer practical methods available to adjust the development cost without impacting the ultimate system configuration. Once a system enters the production or operational deployment phase, there are many means available to bring costs in line with budgets, such as reducing the number of total system buys, stretching out the production phase, or reducing the number of flying hours in peacetime operations.

In the past thirty years, weapon systems development costs have been steadily increasing with each succeeding system costing more than the last one. In fact, the cost of developing a new weapons system may become a factor in deciding whether a new system is procured or not. Clearly, there is a need to reduce the cost of developing new military systems. Besides the obvious benefit of saving real dollars at the most critical point in a weapon system's life cycle, lowering development costs could help tip the scales in favor of developing a new system as opposed to modifying an existing system. Studies have shown that a new system usually offers significant capability and performance benefits, as well as cost benefits, over those of a derivative weapons system[1]. Reducing the cost of developing new weapons systems also can mean that more systems could be developed within a constrained budget, a situation that is most favorable to sustaining our industrial base. A new weapon system, rather than a derivative or modification also offers the best opportunity for technology advancement and for technology transition into the hands of the nation's warfighter.

Paper presented at the RTO AVT Symposium on "Reduction of Military Vehicle Acquisition Time and Cost through Advanced Modelling and Virtual Simulation", held in Paris, France, 22-25 April 2002, and published in RTO-MP-089.

The Engine Development Process

The acquisition reform process has been an ongoing Department of Defense (DoD) activity since the early 1960's. A formal description of the way the DoD procures new systems is called the Defense Systems Acquisition Management Process and it is shown in figure 1. The acquisition management process is characterized by four major program milestones and phases. A new weapons system procurement officially begins with the establishment of a systems program office, or SPO. This occurs once approval is granted to conduct concept studies to define a weapon system that meets a required mission need. After conceptual studies are conducted, the next major milestone is the approval to proceed to the program definition and risk reduction phase. This phase was formerly known as concept demonstration and validation, or dem/val, for short. The purpose of this phase is to identify major system alternatives, identify technical risk and economic uncertainty, and to prove, through demonstration, that the associated technologies and processes are understood and are attainable.

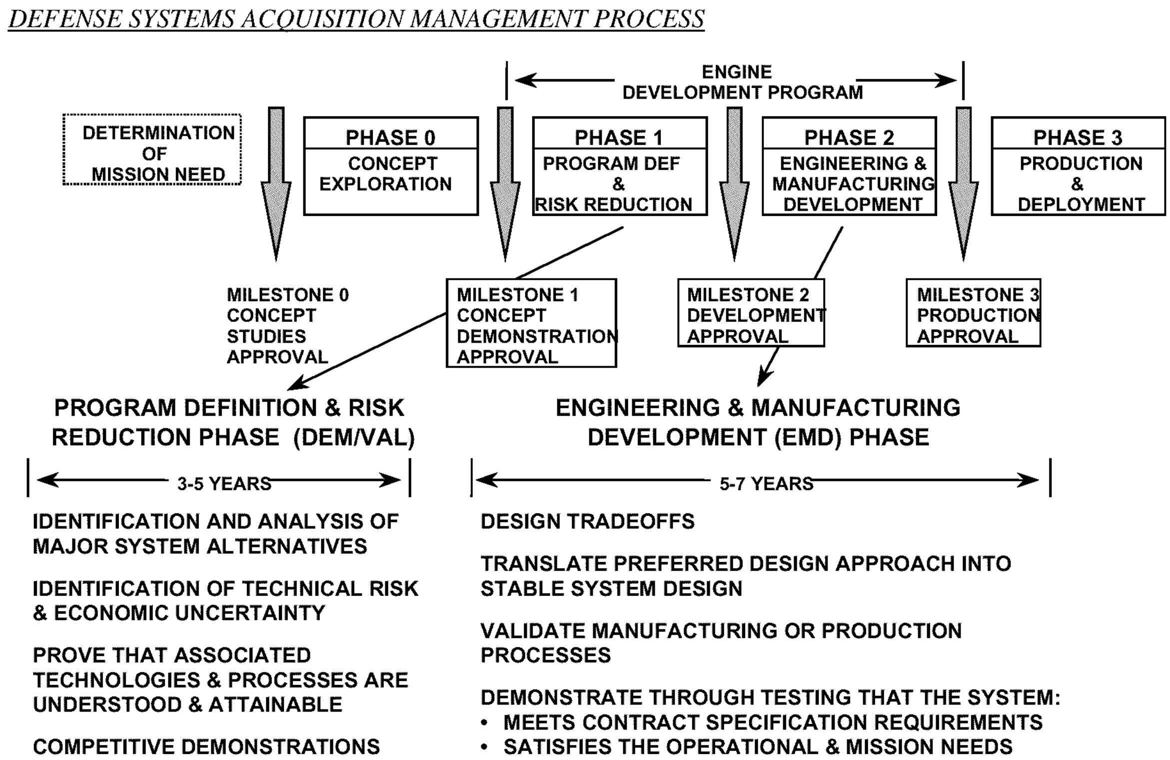
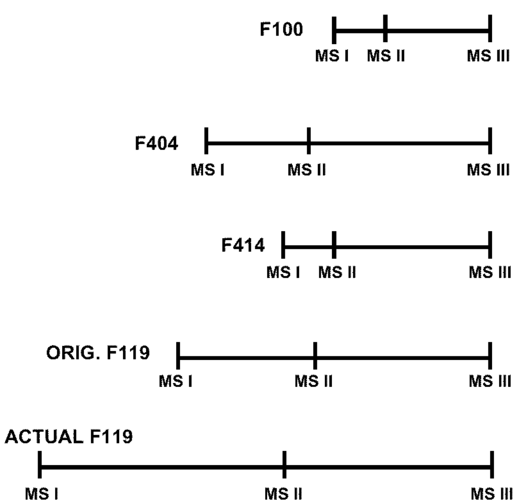


Figure 1. Definition Of Engine Development Program

Once this effort is completed, approval would be granted to move into the next phase of the acquisition process: the engineering and manufacturing development (EMD) phase. In the EMD phase, design tradeoffs are completed and a final design is chosen. After that, two significant activities take place concurrently. The first is to validate the manufacturing processes that will be employed during the production and deployment phase. The second is to demonstrate through testing that the system meets the contract specification requirements and satisfies the operational and mission needs. After the EMD phase, approval would be sought to enter the final program phase, the production and deployment phase. The accepted definition of a development program is defined as the Program Definition and Risk Reduction and EMD phases of the acquisition management process and it is the definition used in this paper. The general acquisition management process shown in figure 1 applies to any military systems procurement. In figure 1, the length of the Program Definition and Risk Reduction and EMD phases shown are typical of those for a new military gas turbine engine development program. For an aircraft or other major subsystem, those times will be different.

Historical Perspective

Figure 2 represents a historical snapshot of military gas turbine engine development programs for fighter aircraft over the past thirty years. An analysis of this historical information yielded some interesting insights into the major program activities and cost drivers that characterize and define an engine development program. First of all, it is apparent that no two engine development programs in recent history are exactly alike. In general, the length of each succeeding engine development program has increased, however, the number of test engines and test hours has decreased. It should be noted that the Navy's F414 engine is considered to be a low risk derivative of the F404 engine, despite the fact that the F414 is about 25% larger than the F404. Since the F414 is a derivative engine, it follows that the length of the program would be shorter. In figure 2, there are two entries for the F119 engine development program. The actual F119 development program was modified shortly after it began to include a prototype demonstration, which occurred between the Dem/Val and EMD phases of the program. The principal purpose of the prototype demonstration was to support the aircraft flight test evaluations of the YF-22 and YF-23 prototype aircraft. The addition of the prototype demonstration added additional time and cost to the original F119 engine development program. During the time period shown in figure 2, a major change in engine development philosophy occurred and what is not readily apparent from figure 2 is how this military engine development cycle has evolved. In the days of the F100, an engine development program concluded with a 150-hour military qualification test (MQT). After that, the engines were produced and put in the field. Any problems that were encountered in the field were addressed during what was known as a component improvement program or CIP. By contrast, the F119 must demonstrate failure free operation within an expected service life of about 5,000 hours in the EMD portion of the development program. Figure 3 shows a comparison of the development program requirements for the F100-100, the F100-220, and the F119-100 engines. The requirements have increased tremendously over this relatively short time period[2]. Over the years there has been an increased emphasis on increasing engine reliability and durability, and the benefits are obvious. Today's engines are better in every aspect of performance and durability than their predecessors. Also, emphasis on reducing radar and infrared signature, and multi-axis thrust vectoring exhaust nozzles have introduced additional elements of cost. These are some of the factors that have driven the cost of developing a new engine upwards.



	DEV. TIME = MOS	# DEV. ENGS	DEV. HRS	FY96 COST	LIFE
F100	54	23	9,628	$1.41B	150 HRS
F404	98	14	15,000	$1.05B	4000 HRS
F414	72	14	10,000	$941M	4000/8000 TAC's
ORIG. F119	108	11	9,683	$1.47B	4000/8000 TAC's
ACTUAL F119	156	9	8,677	$2.465B	4000/8000 TAC's

Figure 2. Historical Summary of Military Gas Turbine Engine Development Programs

F100-100 (CIRCA 1970)	F100-220 (CIRCA 1980)	F119-100 (CIRCA 1990)
• PERFORMANCE FOCUS • MINIMAL ANALYTICAL UNDERPINNING • ITERATIVE TAAF APPROACH (Test, Analyze and Fix) • LIMITED INSTRUMENTED TESTING • NON-REPRESENTATIVE ENDURANCE TESTING (QT) • INSUFFICIENT ANALYTICAL & EMPIRICAL TOOL SET • LITTLE ATTENTION TO LIFE MANAGEMENT	• BALANCED FOCUS BETWEEN PERF. & DURABILITY • MATERIAL CHARACTERIZATION • INCREASED EMPHASIS ON ANALYSIS • ATTENTION TO ACTUAL ENVIRONMENT/USAGE • REPRESENTATIVE ENDURANCE TESTING (AMT) • DAMAGE TOLERANCE DESIGN APPROACH FOR SAFETY CRITICAL COMPONENTS • FULL LIFE TESTING OF MAJOR STRUCTURAL COMPONENTS	• APPLICATION TO ALL SUBSYSTEMS/COMPONENTS • EXPANSION OF PROCESS TO ALL FUNCTIONAL DISCIPLINES (PERF, OPER, ETC) • EXTENSIVE ANALYTICAL RIGOR IN DESIGN • COMPREHENSIVE ENVIRONMENT/RESPONSE CHARACTERIZATION • PROOF/MARGIN TESTING • DAMAGE TOLERANCE EXTENDED TO MISSION CRITICAL COMPONENTS • EXTENSIVE COMPONENT, SUBSYSTEM, & SYSTEM LEVEL "SMART" TESTING • PROCESS DEVELOPMENT & MATURATION IN EMD

Figure 3. Evolution of the engine development process

Notional Engine Development Program

In spite of the fact that the engine development process has changed significantly over the recent past, an average, or notional, engine development program can be defined, by taking a weighted average of the F100, the F404, the F414 and the originally proposed F119 engine development programs. The notional development program is a ten year, $1.5B effort, involving the fabrication and assembly of 14 test engines, 9 flight test engines and includes over 11,000 hours of engine test. The culmination of this effort is a fully qualified gas turbine engine ready for production. Despite some significant differences in program development cost over the time period depicted in figure 2, the cost distribution among the major tasks of each engine development program has remained relatively constant. This cost breakout and the schedule for the notional engine development program is shown in figure 4.

Based on the notional engine development program costs shown in figure 4, it is apparent that in order to make any significant reductions in engine development cost it will be necessary to attack the largest cost contributors. Those are the cost of engine hardware (tooling, fabrication and assembly) and the cost of engine testing. Clearly, both of these factors are not independent, as the number of test articles is a direct function of the type and number of test hours required in the program. The objective of an engine development program is to demonstrate through test, including flight test, that an engine meets the contract specification requirements and satisfies the operational and mission needs for which it was intended. There are practical limits, in terms of time and cost, on how well a test program can actually emulate operational conditions. An inverse relationship between the amount of engine testing and the level of risk associated with meeting the contract specifications has long been recognized. Obviously, there are trade-offs to be made, but there has historically been, a justifiable reluctance to make any compromises when fielding a system for fear of not meeting the intended operational and mission needs.

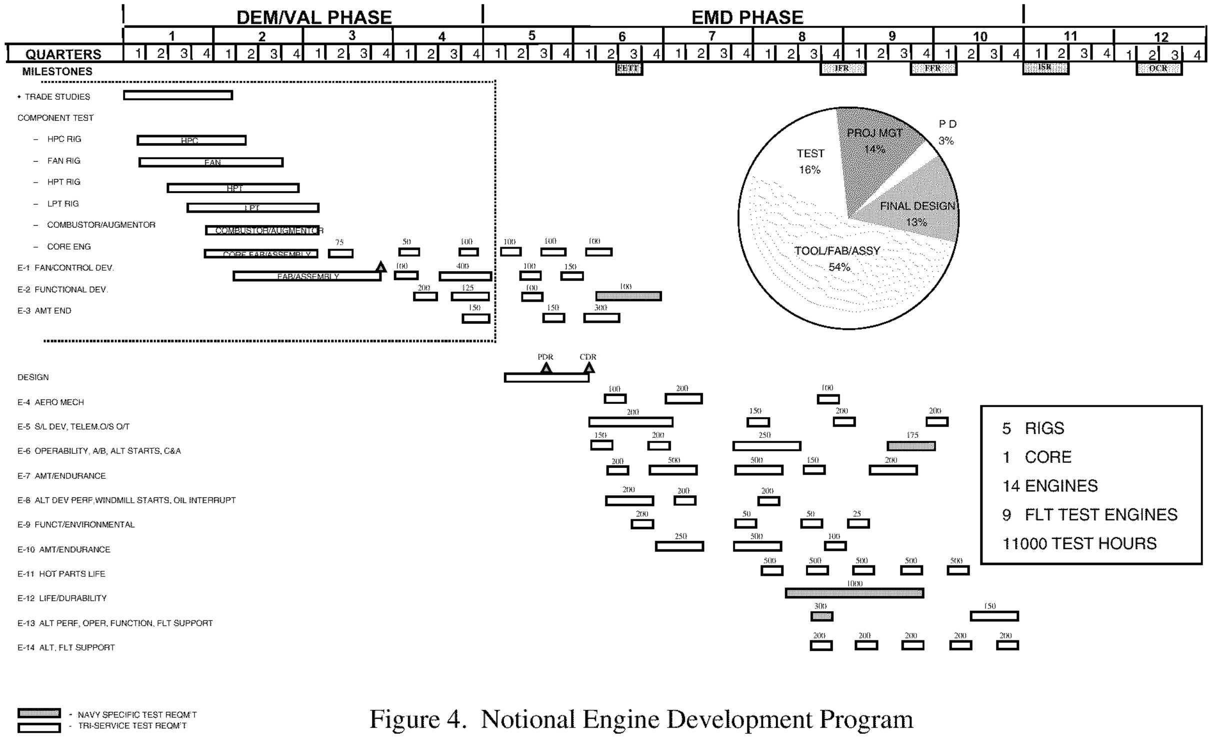


Figure 4. Notional Engine Development Program

The Key to Reducing Costs

The objective of any realistic cost reduction effort would be to reduce the amount of engine testing, and thereby the number of test engines necessary for an engine development program, without adding any undo risk to the overall program. All new engines under development will experience problems along the way. Serious problems that arise during the test portion of the development program that which require a major engine or component redesign to resolve are going to be very costly to correct. The kind of serious problems that would require such an action would be ones that cause the engine to fall far short of meeting operational needs or impact flight safety.

One vital key to reducing the cost of an engine development program is to identify and correct problems as early as possible in the program[3]. Obviously, the earliest time to do that is during the design process when engine hardware, the costliest element of an engine development program, is yet to be made. The key, then, to reducing engine development cost is to develop better simulation and design tools that accurately predict the physical phenomena occurring within the engine. With better design tools, the engine's performance, operability, life, structural integrity and durability can be estimated with greater precision. If the estimation accuracy can be raised high enough, dedicated engine testing to verify these metrics can be significantly reduced. This reduction in test hours means that fewer test engines will be required, thus resulting in further cost reductions. Having better design tools will also impact the other elements of an engine development program, namely the design activity and program management.

The benefits of advanced, computer-aided design methods have been documented throughout the technical literature. The most notable and dramatic example to date may be Boeing's experience using the Dassault/IBM CATIA (Computer Aided Three-Dimensional Interactive Application) design software during the development of the Boeing 777 aircraft[4]. The commercial development of computer aided design, engineering and manufacturing (CAD, CAE and CAM) software has become an emerging growth industry worldwide and it's development continues to evolve dramatically. Figure 5 shows the historical evolution of CAD/CAM/CAE software in terms of its analytical capability and also attempts to predict the type of computer aided design tools that might be available in the future.

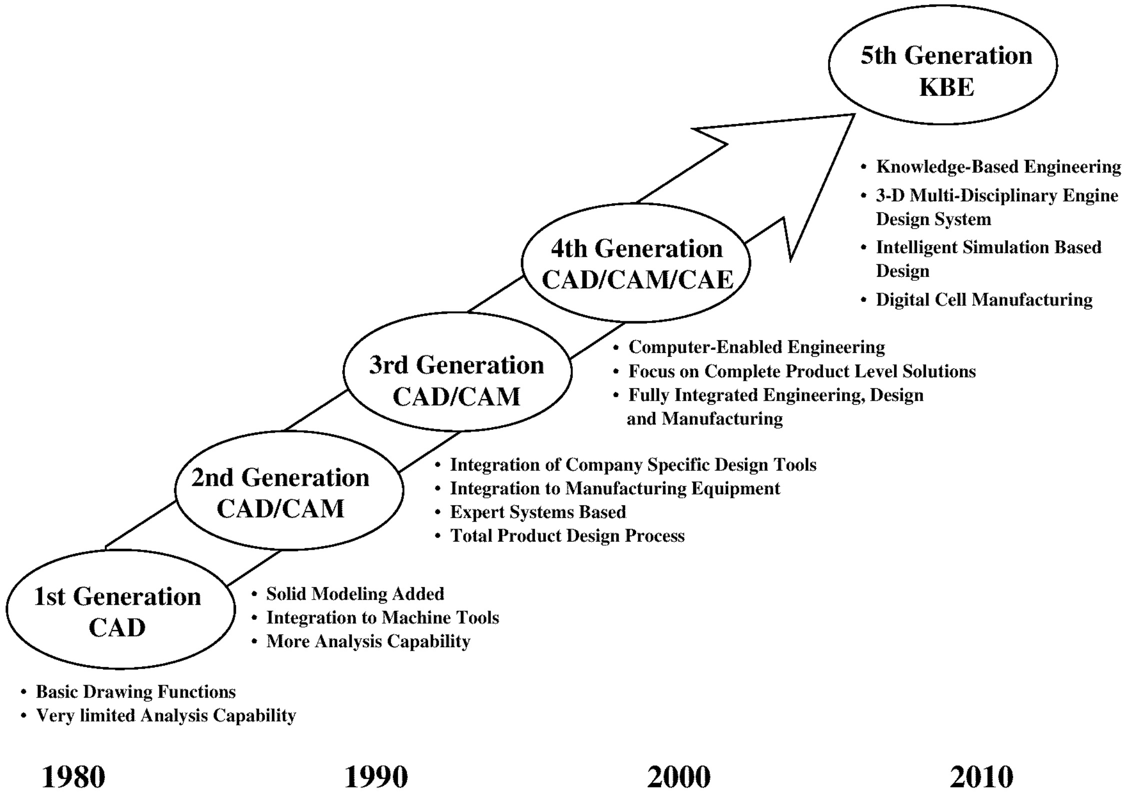


Figure 5. The Evolution of Computer Aided Design, Manufacturing and Engineering Systems

The evolution of computer aided design software has followed the explosive development of microprocessor technology. Early CAD systems were limited to basic 2D drawing capability. As CAD systems evolved, the integration with numerically controlled machine tools soon followed, and the era of computer aided manufacturing emerged. As the evolution continued, more and more analytical capability was added. Today, detailed two-dimensional aerodynamic, thermodynamic and structural analysis and design software packages are routinely available to design engineers.

In order to have a major impact on engine development cost, the predictive accuracy of advanced simulation and design tools will have to improve significantly. The required accuracy of such a design system is shown in Table 1. To illustrate the level of improvement required, an estimate of the accuracy of today's current predictive capability is also shown in Table 1.

PHYSICAL PHENOMENA		TODAY'S ACCURACY	REQUIRED ACCURACY
Performance (Steady State & Transient)		+/- 2.0 %	+/- 0.5 %
Operability		+/- 20.0 %	+/- 2.0 %
Aerothermodynamic		+/- 3.0 %	+/- 1.0 %
3D Structural		+/- 5.0 %	+/- 2.0 %
HCF/Fracture Mechanics		+/- 20.0 %	+/- 10.0 %
Performance Integrated with Control		+/- 2.0 %	+/- 0.5 %
Life	- LCF	+/- 25.0 %	+/- 5.0 %
	- HCF	+/- 100.0 %	+/- 20.0 %
	- Oxidation Resistance	+/- 10.0 %	+/- 5.0 %
	- Stress Rupture	+/- 10.0 %	+/- 5.0 %
Material Properties		+/- 10.0 %	+/- 5.0 %

Table 1. Modeling and Simulation Accuracy

To meet the improved accuracy goals, future, automated design software tools should focus on the development of highly accurate, three-dimensional, multi-disciplinary engine design systems. Multi disciplinary, in this context, means the ability to include aerodynamic, thermodynamic, structural and secondary flow together within the same design package.

The term being applied to this future capability is Knowledge Based Engineering and it implies a higher level of capability and interaction. These systems would incorporate years of design experience, lessons learned and knowledge in a rules-based design system, so that moderately experienced engineers could use them with confidence.

This comprehensive interaction during design is depicted in Figure 6 and it shows that the 3D multidisciplinary design system is at the heart of the overall process. The mission parameters and engine cycle requirements become the principal input to the design system. The principal output is a solid geometry master model of the engine configuration that meets all of the desired performance and life requirements. The solid geometry master model, in the form of an electronic computer file, will interface with and facilitate the manufacturing process, including tooling design and fabrication, the engine assembly and functionality, and the oversight and management of the program.

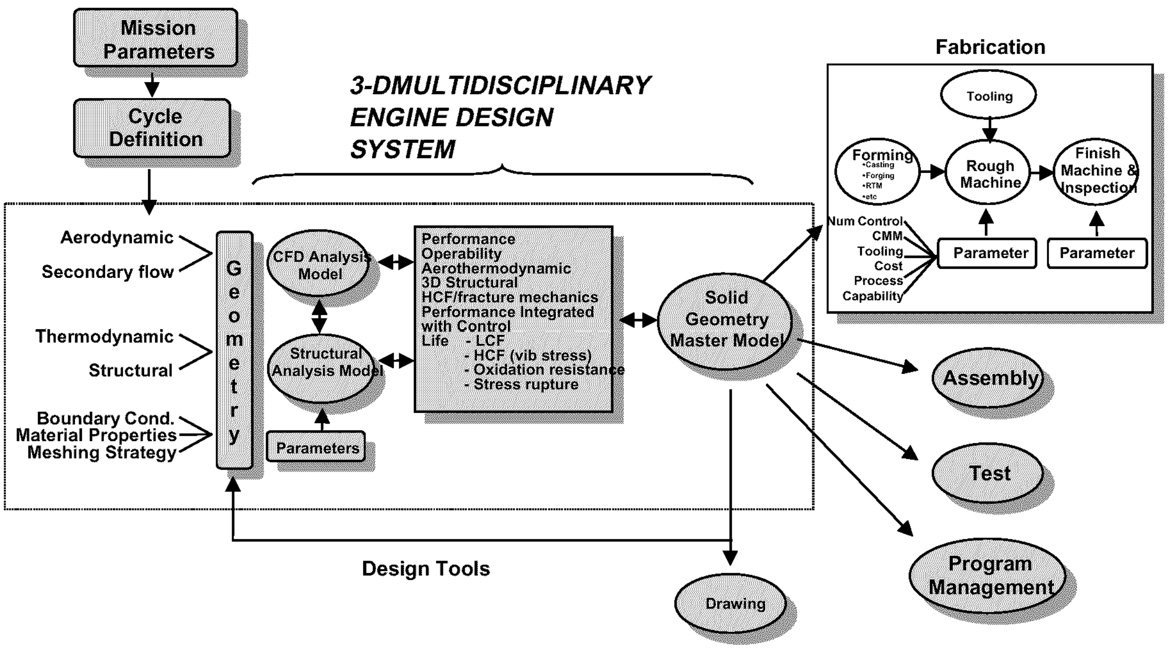


Figure 6. The Role of Design System in the Engine Development Process

The Reduced Cost Engine Development Program

What would be the impact of this improved modeling and prediction capability on the cost of an engine development program? First of all, the new design tools would shorten considerably the amount of time to arrive at a final engine design and greatly improve the design itself.

Historically, about 3 major redesigns would occur during an engine development program just to correct design deficiencies uncovered during the test phases of the program. It is anticipated that no major engine redesigns would be necessary with the advent of these new design tools. Secondly, these design models would permit the establishment and use of a "virtual engine test cell" whereby the engine's performance and operability characteristics could be verified and validated via simulation prior to actual hardware testing. This would lead to a reduction in the amount of actual engine testing required, and, in turn, would lead to a reduction in the number of engines needed in the development program. All aspects of an engine development program would be impacted, including program management. The following section describes in detail the cost analysis that was done to determine the impact of advanced design and simulation tools on a new engine development program.

In order to determine the impact of a "virtual test cell" on the amount of engine testing required in an engine development program, it is prudent to first examine the purpose of an engine test program. Generally, the requirements fall into two broad categories: verifying engine performance and ensuring safety of flight. A typical set of engine test requirements for an engine development program is shown below in Table 2.

- Fan/Compressor Aeromechanical Performance
- C&A Environmental
- Altitude Performance
- Augmentor Development
- Low Pressure Aeromechanical Performance
- Envelope Exploration
- Stall Margin/Operability
- Inlet/Engine Compatibility
- Control Optimization
- Pressure/Thermal Surveys
- Heat Rejection
- Oil & Electrical Interrupt
- Overspeed & Overtemperature
- Accelerated Mission Test
- Ingestion: Water/Ice/Birds
- Vibration/Critical Speeds
- Blade Out/Containment
- Windmill/Altitude Start

Table 2. Typical Engine Test Requirements

Table 2 illustrates just how broad the scope of the overall test activity is. Simulated engine testing would greatly impact some of the test requirements in table 2 and have little or no impact on others. For example, it would be relatively easy to verify aerodynamic performance with simulation, but quite hard, if not impossible, to verify blade-out containment with simulation. The type of test hour reductions that may be realizable with advanced design and simulation tools is shown in Table 3.

This represents an overall reduction in total engine test time of about 30 percent. Accordingly, the number of engine hardware sets required to support the engine test program would drop from 14 to 9.

Test Activity	Notional	Proposed
Aero/Mechanical	775	400
Functional/Environmental	675	500
AMT/Endurance	3225	2875
Operability (SL)	750	450
(Alt)	2595	1325
Hot Part Life/Durability	3000	2000
Total Test Hours	11020	7550

Table 3. Test Hour Reduction Potential

Secondary cost benefits would also be realizable. As indicated in figure 6, the output of the 3D multidisciplinary design system is a solid geometry master model. This master model would become an integral part of a seamless set of software modules that would interface with all other aspects of the program operation, from human resources, contracting, finance, manufacturing and planning. The term enterprise resource planning, or ERP, has recently been coined to describe the aerospace and defense companies efforts to reengineer and computerize all aspects of their operations as a means of reducing cycle times and costs [5].

The solid geometry master model would become a data input data to computer aided manufacturing software tools to design the tooling fixtures, casting molds and forging dies with greater precision. First-time quality will be greatly improved, reducing rework on manufactured parts by 50%. The electronic data files describing the solid geometry master model would provide an accurate and seamless interface among the designers, manufacturing and outside vendors and suppliers, ensuring and enabling integrated product development (IPD). Form, fit and function could be accomplished electronically, eliminating the need for mock-ups and reducing the cost and time associated with assembly.

The ability to instantaneously transfer data electronically, and to conduct paperless design and test reviews will impact the number of support staff and the number of programmatic meetings. Once again, the key enabler to reducing program management costs is the existence of the 3-D, solid geometry master model that is created by the advanced design system. Technical and programmatic performance can be tracked daily with a system that is accessible, flexible and easy to understand. Table 4 describes the groundrules and assumptions that were used in the cost analysis.

Development Activity	Notional	Proposed
Tooling Cost	$ 90 M	$ 45 M
Fab & Assembly/Engine	$ 45 M	$ 30 M
Rig: Fab/Assembly/Test		
- Fan/Comp, C&A	$ 10 M	$ 7 M
- Comb/HPT/LPT	$ 4 M	$ 2.8 M
- Aug/Noz/Mech Sys	$ 2 M	$ 1.4 M
Ave Test Cost/Hour	$ 18.5 K	$ 20 K
- Sea Level	$ 15 K	$ 18 K
- Altitude	$ 25 K	$ 30 K
- AMT/Endurance	$ 10 K	$ 10 K
- Specialized	$ 60 K	$ 60 K
Ave # of Design Iterations	~ 3	~ 1.2

- All Costs based on FY 90 $'s
- No flight test activity in DEM/VAL
- No significant program redirection & sufficient funds are available to maintain the program schedule

Table 4. Groundrules and Assumptions

A 50% reduction in tooling cost was assumed due to the impact of automated tooling design based on the solid geometry master model and a reduction in the number of design iterations needed to achieve a final product definition. A 33% reduction in the average engine cost in the development program was assumed due to the reduction in the number of engines required, the anticipated reduction in required rework, the improved quality, the reduction in manufacturing lead times, and improvements in assembly [6].

Similarly, the cost of fabricating, assembling and testing rig hardware would be reduced by about 30%. In the analysis of rig costs it was observed that the rig costs varied by component. Fan, compressor and controls and accessory rig tests cost on the order of $10 M apiece; combustor and high and low pressure turbine rig tests cost about $4 M; and augmentor, exhaust nozzle, and mechanical systems cost on the order of $2 M each. There were exceptions to this rule. The F119 engine is a two-spool, counter-rotating engine with a 2D, thrust vectoring exhaust nozzle. Both the nozzle rig, which used sub-scale hardware which helped defer some of the cost, and the counter-rotating bearing rig were more expensive. In evaluating rig costs, a factor that should be considered is the level of technology involved in the new engine design. This will often times dictate whether a rig test is needed or not.

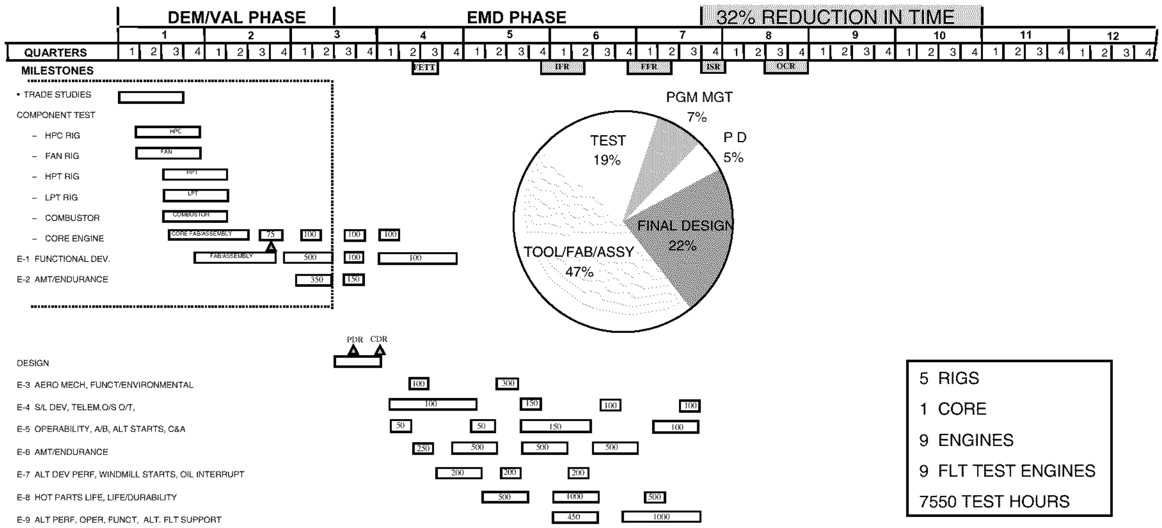


Figure 7. Proposed Reduced Cost Engine Development Program

One more thought concerning rig hardware and tests is offered. Some engine manufacturers have discussed eliminating rig tests because their design systems are so good. In the author's opinion, that would not be a wise thing to do. While eliminating rig tests sounds impressive, it violates one of the axioms surrounding the reduction of engine development cost. That is that cost is dependent on when problems are discovered and corrected. Rig tests represent a small fraction of a total engine development program's cost, more importantly, they offer the first opportunity to verify a design through actual hardware tests, and for this fact alone, they are a bargain.

Full-scale hardware tests were assumed to increase in cost by about 20%. This is to account for an anticipated increased level of post-test analysis featuring the improved simulation tools and an increase in the amount of on-engine instrumentation to support that analysis. This increased cost per test hour will be more than offset by a reduction in the number of test hours required. Like rig tests, full-scale engine test costs vary by the type and nature of the test. The costs shown in Table 4 include all costs associated with an engine test, including engineering support and facilities. Specialized tests, such as FOD tests, blade out containment, cold soak starting, etc. are very expensive due mainly to the unique test facilities required and possible hardware losses. Fortunately the total test time for these types of tests is relatively low.

The groundrules and assumptions depicted in Table 4 were factored into the framework of the notional engine development program shown in Figure 4 to arrive at an estimate of the cost reduction potential due to improved design tools. Table 5 shows a cost comparison between the notional baseline engine development program and the proposed, lower cost program that takes full advantage of the improved design tools and simulation potential capability previously described. The numbers in parenthesis shown in Table 5, indicate the cost distribution by development activity on a percentage basis for the notional program and for the proposed program.

Development Activity	Notional	Proposed
Preliminary Design	$ 46 M (3%)	$ 37 M (5%)
Final Design	$ 198 M (13%)	$ 160 M (22%)
Tooling/Fab/Assembly		
Rig	$ 30 M (2%)	$ 22 M (3%)
Core/Engine	$ 481 M (32%)	$ 164 M (22%)
Flt Test Engines	$ 310 M (21%)	$ 156 M (21%)
Test		
Rig	$ 16 M (1%)	$ 16 M (2%)
Core/Engine	$ 202 M (14%)	$ 126 M (17%)
Project Mgt/Other	$ 213 M (14%)	$ 52 M (8%)
Total	$ 1496 M	$ 733 M

Table 5. Development Cost Comparison

These percentages are interesting in that they could indicate a shift in the development program philosophy in favor of increased emphasis on the upfront design activity. From a cost viewpoint, savings on the order of 50% are potentially realizable for a new engine development program.

The cost distribution and a program schedule for the proposed reduced cost engine development program are shown in Figure 7. With the advanced design tools and simulation capability, a 32% reduction in program length is possible. This represents a reduction in program length of 39 months. The number of test hours is reduced by over 30% and the test costs can be reduced by about 35%.

The largest area of cost reduction potential lies in the cost of hardware. Specifically, this includes the cost of tooling, fabrication and assembly of rig test hardware, engine test hardware and the engine hardware needed to support a flight test program. The number of flight test engines was fixed at 9 for both the notional and proposed development programs in this analysis. Moreover, the number of engines directly involved in the development activity falls by over 36%, while the total hardware costs fall by nearly 60%. There are three principal factors contributing to this dramatic reduction in hardware cost. The largest contributor is due to the reduction in the number of major engine redesigns, followed by the reduction in the number of engines required and, finally, the reduction in tooling costs.

In the proposed program, program management costs are reduced by 70% compared to the notional engine program. These projected savings are due to the overall reduction in the length of the program, the reduction in engine hardware, and in test hours. Another factor that will contribute to the reduction in program management costs is the anticipated impact of enterprise resource planning tools which will permit effortless, daily tracking of the program's cost, schedule and technical progress interactively with very few support personnel.

Summary

The engine is one of the few subsystems that have a positive impact on an aircraft weapons system. For a given mission requirement, using a high thrust to weight ratio engine translates into a smaller, lighter and less costly aircraft. In spite of these obvious benefits, the cost of developing a new high performance military aircraft engine is becoming prohibitively more and more expensive, as the requirements for each new engine seems to be increasing without bound. Clearly, there is a need to reduce the cost of future military engine development programs without compromising the basic program requirement to demonstrate that an engine satisfies all of the operational and mission needs for which it was designed.

An analysis of the engine development process indicates that significant cost reduction potential is possible if improved computer-aided design tools and simulation techniques can be developed. The predictive accuracy of these advanced software tools has been defined. With these improvements, the design effort can be shortened considerably and the number actual engine test hours would be significantly reduced. This would lead to a dramatic reduction in the number of test engines required to conduct an engine development program. Subsequently, the length of the development program may be reduced by a third. All of these factors contribute to the potential cost reduction of an engine development program that is on the order of 50%.

Acknowledgements

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Paper Keynote #5
Discussor's name R. McClelland
Author Skira

Q: 1. Is there any hope of reduction of air flight safety test hardware?
2. Are there any actual development programs underway using this vision?

A: 1. No-difficult problem
2. No-not yet